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GB 2386026 A
GB 0734672 A
GB 0714919 A
WO 2003/001841 A2

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INT CL[7] H04R
Other: ONLINE: WPI, EPODOC, JAPIO

(54) Abstract Title: **Hinged-type piezoelectric loudspeaker**

(57) The loudspeaker has a flat sound emitting panel 25 mounted onto a support structure and at least one electroactive actuator 26 adapted to rotate said membrane around a hinge 212. The actuator 26 is effectively decoupled from excessive motion or resistance to motion of the panel by coupling element 261.
The panel 25 may be transparent to form an outer protective cover for the display of a radiotelephone (Fig 3).

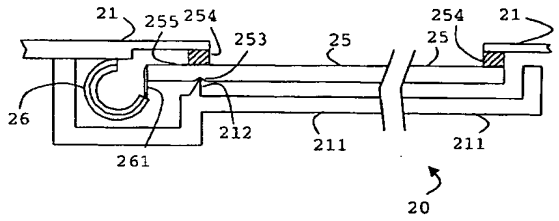

FIG. 2A

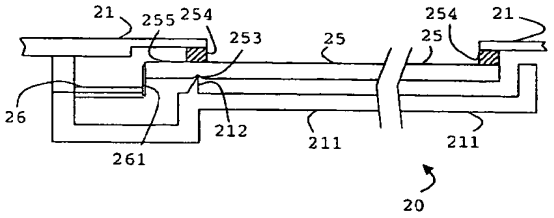

FIG. 2B

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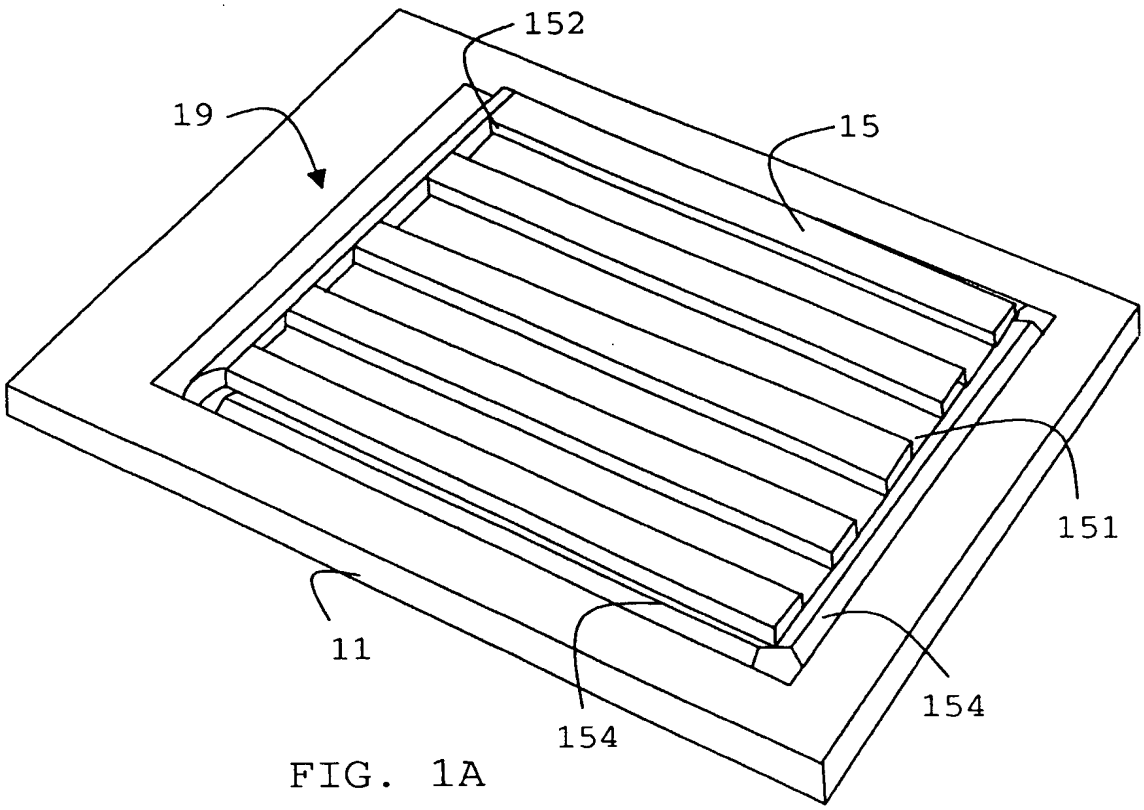

FIG. 1A

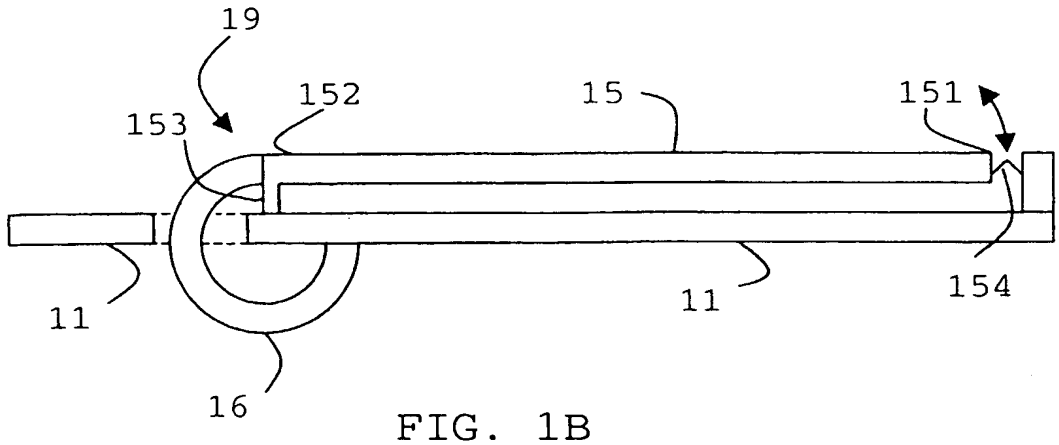

FIG. 1B

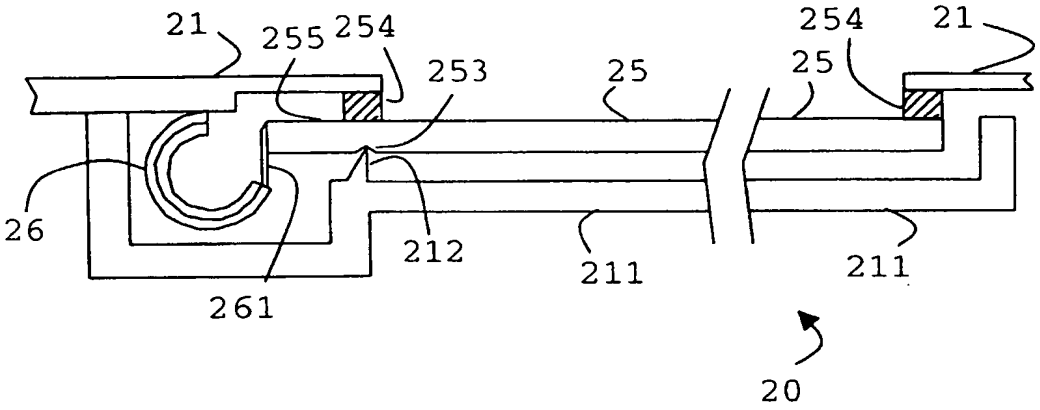
21
255
254
253
25
254
21
25
26
212
211
211
261
20

FIG. 2A

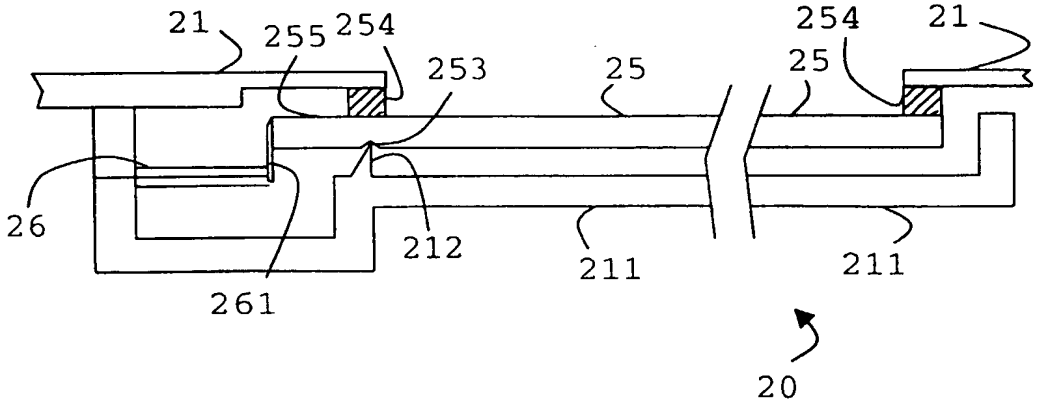
21
255
254
253
25
254
21
25
26
212
211
211
261
20

FIG. 2B

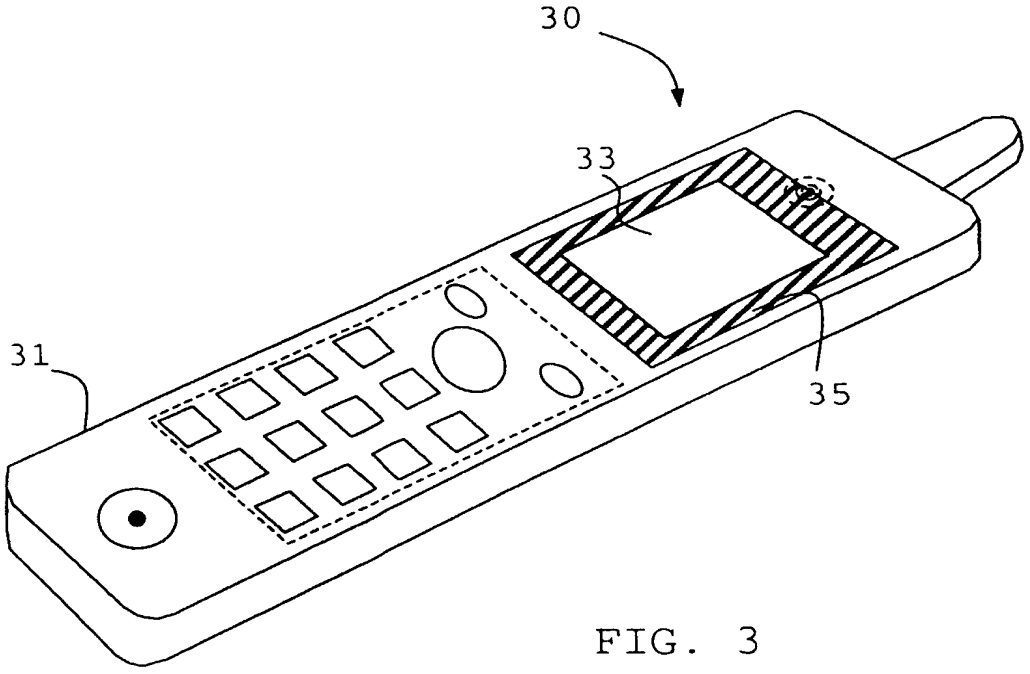

FIG. 3

RUGGED ELECTROACTIVE LOUDSPEAKER DESIGN

FIELD OF THE INVENTION

The present invention relates to rugged loudspeaker systems driven by actuators made of piezoelectric materials. It relates particularly loudspeakers with a panel type diaphragm. More specifically, it relates to such loudspeakers for use in portable electronic devices such as mobile phones, personal digital assistants (PDAs) and laptop computers.

BACKGROUND OF THE INVENTION

In mobile communication and data processing equipment, the generation of audible sound, buzz tones or vibration are handled by systems mostly driven by electro-magnetic actuators.

Sound is usually generated by, albeit small, voice-coil driven loudspeakers, whereas number of reasonably inexpensive and effective constructions have evolved for providing signal units to generate the necessary tones or vibrations for these devices. These include miniature motors with imbalanced rotors to create a sensible vibration; small piezoelectric assemblies to vibrate at an audio frequency and create a tone or beep ("buzz") noise; and other, older technologies such as speakers with an electromagnetic voice coil, or a magnetic solenoid driving a diaphragm to create a sound such as an audio tone or a vibratory buzz. Many of the current mobile phones use separate components for vibration alert, audio alert and speech or music reproduction.

Also, it is desirable for most portable devices to a have a "hands-free" mode, i.e., a mode that allows a user to communicate through the device without having to use his or her hands. In order to operate portable phones in a hands-free

mode, a high power output is required over a frequency range of 300 to 3400 Hz, often referred to as the speech band. At present the hands-free mode of commercially available products is exclusively implemented through common electro-dynamic or moving coil loudspeakers.

In the commonly-owned international patent application PCT/GB2002/02836 filed 19 June 2002 and entitled "LOUDSPEAKER" there are described various devices and methods to generate sound comprising a support on which is mounted an electro-active actuator, which is in turn coupled to an area-extensive section of the case of the device, which section of the case acts as the sound generating element of a loudspeaker. In other embodiments illustrated therein the sound generating element is an interior element of the portable device, such as a printed circuit board (PCB). Also described therein is an embodiment comprising a sound generating element attached to the support structure by a hinge element attached to a first edge and driven in operation by the electro-active actuator preferably acting upon an opposite edge of the sound generating element. Various other examples describe hinged panel-type loudspeakers that are driven by an electroactive actuator positioned in proximity of the hinge section.

In view of the above, it is the purpose of the present invention to provide a panel loudspeaker driven by an electro-active actuator. For many portable applications, such a loudspeaker system requires a certain ruggedness to withstand everyday use. In contrast, ceramic materials, including the electro-active materials the actuators for such loudspeakers are made of, are brittle materials and prone to break when handled without sufficient care.

SUMMARY OF THE INVENTION

Accordingly, the present invention provides a loudspeaker system that comprises an essentially flat sound emitting surface or panel and a supporting frame or structure onto there is mounted an electro-active actuator, which is in turn coupled to the sound emitting surface such that the actuator is capable of rotating the sound emitting surface at a hinge section, wherein the decouples the actuator from movements of the panel caused by an external load or force acting on it.

In a particularly advantageous variant of the invention the coupling between the actuator and the panel includes one or more flexures or compliant elements. The use of flexures is regarded as particularly advantageous as in many cases the motion of the actuator may not be strictly confined to a desired path, such as a pure rotational motion. The distal or the free end of a piezoelectric bender or rotator of more complex nature is likely to describe a motion including lateral and other unwanted movements. A suitable flexure in the coupling can reduce strains and torques potentially caused by these parasitic movements.

There are further provided end stops that prevent any motion of the panel exceeding a predefined amplitude. The end stops are preferably part of the housing that seals the loudspeaker system. In a particularly preferred variant the end stop is provided in form of a back panel arranged in parallel to the inner face of the sound emitting panel at a distance that essentially predefines the maximal travel or amplitude of the sound emitting panel.

In another preferred variant of the invention the hinge section includes an edge that forms the contact point or line between the panel and the supporting structure. The line

contact offers the least resistance to the desired rotational motion of the panel while simultaneously effectively isolating the actuator from any bending motion of the panel as may be induced by an external force.

The ruggedness of the loudspeaker system may be further enhanced by a sealing arrangement of gaskets providing a fluid- and dust-tight seal between the outer face of the panel and the surrounding parts of the frame. Through pre-compression the gasket can also be used to exert some pressure that forces to the panel against the above-mentions edge of the hinge, thus maintaining its position.

By making at least parts of the sound emitting panel and, where required, of its back panel transparent, the rugged loudspeaker system of the present invention is particularly suited to cover the display area of a device. By combining the loudspeaker with the display cover, the dimensions of the outer shell of such device can be further reduced and any space, previously used for sound emission, is freed for other uses.

Electro-active materials for use as actuators within the scope of the present invention are those which change shape in response to an electric field (or conversely, generate an electric field when mechanically activated). Electro-active materials include piezoelectric materials, which expand or contract when electrically activated, and electrostrictive materials which contract in an electric field. Examples are piezoelectric ceramics such as PZT (lead zirconate titanate), piezoelectric polymers such as PVDF (polyvinylidene fluride) and electrostrictive ceramics such as PMNT. The basic electro-active effect is very small, typical displacements being no more than a fraction of a micron for a centimeter

sized block of electro-active material when electrically activated. Accordingly, the actuator of the loudspeaker of the invention is not a simple block of electro-active material but is an arrangement of electro-active and electrode materials capable of at least 10 microns of movement.

The electro-active actuator may be of a known construction, such as a piezoelectric actuator stack or one or more benders. Preferably however the actuator is of the coiled-coil type, known as a Helimorph (RM) actuator, as described for instance in the published International Patent applications WO-0147041 (PCT/GB00/04949) and WO-0147318 (PCT/GB00/04953), of the stacked-recurve-bender type or of a C-shaped type. The most efficient of these actuators provide displacements of the order of 100 microns or more from a compact device with dimensions of the order of 20 mm or less (usually at least one dimension is only a few millimeters). Other actuators may be used, as described below when making reference to hinged diaphragm.

These and other features of the inventions will be apparent from the following detailed description of non-limitative examples making reference to the following drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1A is a perspective view of a panel-type loudspeaker system as described in the international patent application PCT/GB2002/02836;

FIG. 1B is a cross-sectional view of the device of FIG. 1A;

FIG. 2A shows a cross-section of an improved panel loudspeaker in accordance with the present invention;

FIG. 2B is another example in accordance with the present invention using a different actuator; and

FIG. 3 is a perspective view of a hinged panel-type loudspeaker in accordance with the invention as transparent cover of the screen of a mobile telecommunication device.

DETAILED DESCRIPTION

In the device of international patent application PCT/GB2002/02836, shown in FIGs. 1A and 1B, a frame structure **11** supports an essentially flat diaphragm or sound emitting membrane **15**. The diaphragm has distal end **151** and a proximate end **152**. At the proximate end the diaphragm **15** is mounted to the support structure **11** by a hinge section **19** that allows a rotational motion of the diaphragm around the axis of the hinge section.

An electro-active tubular element **16** is used to drive the diaphragm **15**. The actuator is essentially C-shaped. Its length is 25mm, and it has an outer diameter of 4.4mm and a tape thickness of 0.4mm. When energized, it is capable of generating an angular movement around it main axis of ±0.33 degrees with a blocking torque of 3.2mNm. This translates to a displacement of the distal end **151** of the diaphragm **15** of ±0.26mm. The equivalent force at this edge is about 0.071N. The mass of the actuator **16** is 0.75g, and the mass of the diaphragm is 0.2g.

The actuator is mounted onto the back of the support structure **11** and extends through a slit in this structure to the proximate end **152** of the diaphragm **15**. It is adopted to exert its force predominantly in direction of the plane of the diaphragm, thereby rotating the diaphragm around the axis of the hinge **19**. A part of the diaphragm **15** and any members **153** extending therefrom provide a small additional lever to further improve the force transfer from the actuator **16** to the diaphragm **15**.

The diaphragm **15** is a made of polycarbonate, hot-pressed into a corrugated shape to enhance its rigidity whilst maintaining a low weight. Other materials displaying a low weight combined with high stiffness such as fiber-reinforced plastics are likely to be equally suitable for use in connection with the present invention. The diaphragm or membrane may have a more complex internal structure including, for example, honeycomb reinforcements sandwiched between two layers of lightweight material and the like.

The membrane has highly compliant edge sections **154** to seal the half-space below or behind the membrane. In the present example the seals are formed by lips of thin polycarbonate and, hence, form an integral part of the diaphragm **15**.

The above example can be rendered more rugged using improvements as proposed by the present invention. In the device illustrated in FIG. 2A, there is shown the loudspeaker system **20** including a flat transparent diaphragm **25** that may serve as a cover layer to a LCD screen (not shown).

The diaphragm **25** is surrounded by part of the casing **21** of the device. An extension of the casing **21** is used to mount an C-shaped actuator **26** of the kind described above. Also extending

from the casing or rigidly connected to it is a back panel **211**. The back panel **211** includes a sharp extended ridge or edge **212**. This edge forms the hinge point around which the diaphragm **25** rotates.

Between the diaphragm **25** and the surrounding casing **21** is placed a compliant and sealing gasket **254**. By being pre-compressed, the gasket forced the edge **212** into a shallow groove **253** in the diaphragm, thus stabilizing the position of the diaphragm **25**.

The diaphragm **25** and the actuator **26** are coupled by flexures **261** made from polycarbonate. This material was found to be sufficiently stiff to provide a good transmission of force in a vertical and hence desired direction whilst being compliant enough to allow for some lateral (in the illustrated case out of the paper plane) and some twisting motion of the moving end of the actuator **26**.

In operation, the C-shaped actuator **26** rotates around its center, moving the flexures **261** up and down. The section **255** of the diaphragm **25** extending from the flexures **261** to the edge **212** provides a mechanical advantage or lever, thus increasing the force exerted on the diaphragm **25**. An audio signal after being converted into a driving voltage for the actuator **26** is translated into a rotational motion of the diaphragm **25** around the edge. This motion causes the diaphragm to radiate audiable sound.

In case an external pressure is exerted onto the flat diaphragm **25** it bends towards the back panel **211**. The back panel **211** acts as an end stop so that the actuator is shielded from this motion and is less likely to break through excessive motion.

In the example of FIG. 2B, the actuator **26** is a bimorph bender that when energized describes a simple vertical motion at its free end. The same numerals are used as in FIG. 2A to denote the same elements as in the above example.

In FIG. 3 a loudspeaker system **30** as illustrated by FIG. 2 is shown as a protective cover over the LCD screen **33** of a mobile telephone. The diaphragm **35** (hatched) is transparent and protects the screen **33**. Using suitable electronic drives circuits (not shown) the cover/diaphragm can be used as to transmit sound to the user's ear.

CLAIMS

1. Loudspeaker for audible sound comprising a sound emitting panel mounted onto a support structure and at least one electro-active actuator adapted to rotate said membrane around a hinge section through a coupling that isolates said actuator from excessive motion or resistance of the sound emitting element.

2. The loudspeaker of claim 1 wherein the coupling includes flexures.

3. The loudspeaker of claim 1 or 2 comprising end stops for the sound emitting panel.

4. The loudspeaker of claim 3 wherein a back panel arranged essentially parallel to the sound emitting panel forms the end stops.

5. The loudspeaker of claim 1 further comprising a compliant seal to prevent entry of liquid or dust between the sound emitting panel and the support structure.

6. The loudspeaker of claim 1 wherein the hinge section includes an edge providing essentially a point contact between the sound emitting panel and the support structure.

7. The loudspeaker in accordance with any of the preceding claims being at least partly transparent.

8. The loudspeaker of claim 7 being positioned over a display.

9. A mobile electronic device including a loudspeaker in accordance with any of preceding claims.

Application No:	GB 0320472.4	12	**Examiner:**	Peter Easterfield
Claims searched:	1 to 9		**Date of search:**	20 January 2004

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
A, P		WO 03/001841 A2	(1...)
A, E		GB 2386026 A	(1...)
A		GB 0734672 A	(WALTON) see 9, figs 2 & 3
A		GB 0714939 A	(ROTHERMEL) see 4, figs 1-4

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[W]:

H4J

Worldwide search of patent documents classified in the following areas of the IPC[7] :

H04R

The following online and other databases have been used in the preparation of this search report :

WPI, EPODOC, JAPIO